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Power Quality Enhancement in Wind Turbine Fed FSIG under asymmetric faults using SVPWM control D-STATCOM

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Abstract

This paper presents the mitigation of faults in wind turbine connected fixed speed induction generator using distribution static compensator because of its excellent performance of fault mitigation. The D-Statcomconsists of current controlled voltage source converter used for reactive power compensation when connected to the power system. The control system of the proposed d-statcom is based on space vector pulse width modulation. The proposed wind turbine fed fixed speed induction generator is evaluated and simulated using SIMULINK/MATLAB environment with and without D-statcomunder asymmetric faults.

Keywords: Fixed Speed Induction Generator, Wind Turbine, space vector pulse width modulation, distribution static compensator

Introduction

The wind power penetration has increased dramatically in the past few years, hence it has become necessary to address problems associated with maintaining a stable electric power system that contains different sources of energy including hydro, thermal, coal, nuclear, wind, and solar. In the past, the total installed wind power capacity was a small fraction of the power system and continuous connection of the wind farm to the grid was not a major concern. With an increasing share derived from wind power sources, continuous connection of wind farms to the system has played an increasing role in enabling uninterrupted power supply to the load, even in the case of minor disturbances. The wind farm capacity is being continuously increased through the installation of more and larger wind turbines. Voltage stability and an efficient fault ride through capability are the basic requirements for higher penetration. Wind turbines have to be able to continue uninterrupted operation under transient voltage conditions to be in accordance with the grid codes. Grid codes are certain standards set by regulating agencies. Wind power systems should meet these requirements for interconnection to the grid. Different grid code standards are established by different regulating bodies, but Nordic grid codes are becoming increasingly popular.

One of the major issues concerning a wind farm interconnection to a power grid concerns its dynamic stability on the power system. Voltage instability problems occur in a power system that is not able to meet the reactive power demand during faults and heavy loading conditions. Stand alone systems are easier to model, analyze, and control than large power systems in simulation studies. A wind farm is usually spread over a wide area and has many wind generators, which produce different amounts of power as they are exposed to different wind patterns.

Wind Turbine Fixed Speed Induction Generator

A. Grid Connected Induction Generator

Grid connected induction generators develop their excitation from the Utility grid. The generated power is fed to the supply system when the IG is run above synchronous speed. Machines with cage type rotor feed only through the stator and generally operate at low negative slip. But wound rotor machines can feed power through the stator as well as rotor to the bus over a wide range known as Doubly Fed Induction Machines.

B. Fixed Speed Grid Connected Wind Turbine Generator

The structure and performance of fixed-speed wind turbines as shown in Fig. 2.1 depends on the features of mechanical sub-circuits, e.g., pitch control time constants etc.

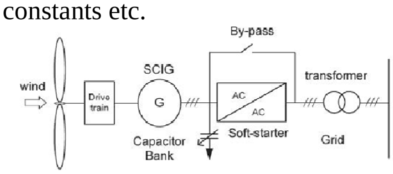

Figure 1 Fixed Speed Wind Turbine With Directly Grid Connected Squirrel - Cage Induction Generator

The reaction time of these mechanical circuits may lie in the range of tens of milliseconds. As a result, each time a burst of wind hits the turbine, a rapid variation of electrical output power can be observed. These variations in electric power generated not only require a firm power grid to enable stable operation, but also require a well-built mechanical design to absorb high mechanical stress, which leads to expensive mechanical structure, especially at high-rated power.

Distribution Static Compensator (D-STATCOM)

The basic electronic block of the DSTATCOM is the voltage source inverter that converts an input dc voltage into a three-phase output voltage at fundamental frequency.

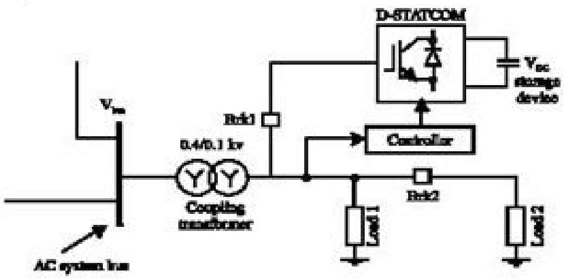

Fig2: Block diagaram of D-statcom

These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of the D-STATCOM output voltages allow effective control of active and reactive power exchanges between the D-STATCOM and the ac system. Fig. 2 shows a typical 12-pulse inverter arrangement utilizing two transformers with their primaries connected in series. The first transformer is in Y-Yconnection and the second transformer is in Y-connectiEach inverter operates as a 6-pulse inverter, with the Y-inverter being delayed by 30 degrees with respect to the Y-Y inverter. The IGBTs of the proposed 12-pulse FD-STATCOM are connected anti parallel with diodes for commutation purposes and charging of the DC capacitor [11]. This is to give a 30 degrees phase shift between the pulses and to reduce harmonics generated from the FD-STATCOM.

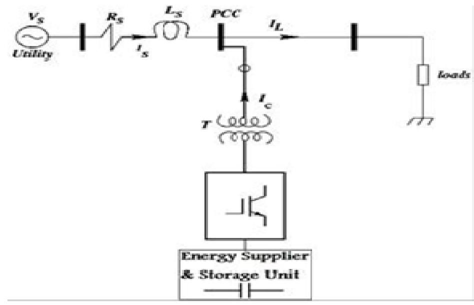

Fig3: D-statcom structure

Control Strategy

Space Vector Based Control

In space vector modulation technique, three phase quantities are transformed to their equivalent two phase quantities, in the stationary reference frame. From these two-phase components, the magnitude of reference vector is computed, which is used for modulating the inverter output .

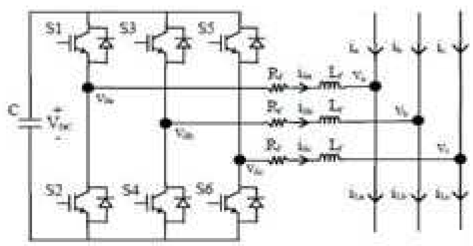

Figure4: STATCOM Configuration.

Space Vector based hysteresis control method is used, in which the desired reference voltage (V_n^*) in eachsector is found by choosing two adjacent non- zero vectors and a zero vector. For example, let the desired outputvoltage vector (V_n^*) be located in Sector I, as shown inFigure-6. To follow the reference voltage vector, ${}^{die}dt$needs to be very small. This condition is satisfied if the voltage vectors adjacent to reference voltage vector (V_n^*) are selected (e.g.V_1 ,V_2 , V_0 and V_7 for Sector I). In this way, two adjacent non-zero voltage vectors and a zero voltage vector (v_0) are selected by the controller toreduce the tracking error. Accordingly, the proposed vector-based current controller generates a switching pattern similar to the well-known Space Vector Modulation (SVM) under steady-state conditions. It should be noted that to produce this optimal switchingpattern, only the sector of V_n^* needs to be determined andnot the exact value of the vector. During transient conditions, non-optimal voltage vectors with high value of derivative of error in current must be applied to force the error vector into the hysteresis band as fast as possible. This would provide a very

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fast transient response for the vector-based current controller.

Table-1.Three-phase switching states, respective voltagespace vectors and their - βvalue

S_a^*	S_b^*	S_c^*	V_n	$\frac{V_\alpha}{V_{dc}}$	$\frac{V_\beta}{V_{dc}}$
0	**0**	**0**	V_0	**0**	**0**
1	**0**	**0**	V_1	**2/3**	**0**
1	**1**	**0**	V_2	**1/3**	$\frac{1}{3}$
0	**1**	**0**	V_3	**-1/3**	$\frac{1}{3}$
0	**1**	**1**	V_4	**-2/3**	**0**
0	**0**	**1**	V_5	**-1/3**	$-\frac{1}{3}$
1	**0**	**1**	V_6	**1/3**	$-\frac{1}{3}$
1	**1**	**1**	V^1	**0**	**0**

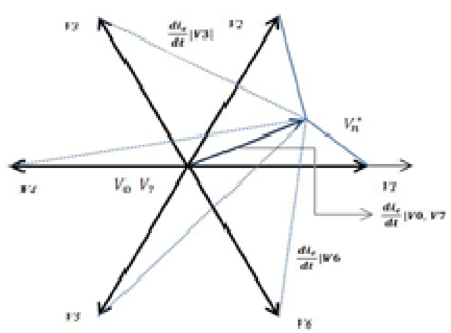

Fig5 :Derivates of error in current vector when V_{ref} is in sector1.

$D\alpha$ \ $D\beta$	0	1	2
0	V_5	V_4	V_3
1	V_5	V_0	V_3
2	V_6	V_0	V_2
3	V_6	V_1	V_2

Fig6: switching table of hysteresis current method

In this paper, SVM based HCC is implemented with multilevel hysteresis comparators for controlling output current of the DSTATCOM. The error in current is represented in stationary (α-β) frame and the error in current vector is controlled to lie within the tolerance region. Figure Below shows the VSC output voltage space vectors in α-βplane. Table-1 gives the possible switching states and corresponding normalized α-βvalues of vectors. It can be observed that there are three discrete levels along βaxis and four discrete levels along αaxis. Hence, to identify the region of the error in the current vector, a four-level hysteresis comparator on αaxis and a three-level hysteresis comparator on βaxis are used. A new voltage vector with the opposite value of α(or β) component is applied when the DSTATCOM output current exceeds the tolerance region on one particular axis. Suppose the DSTATCOM output current is in sector I, and if error exceeds the tolerance region from the bottom (or top) side, the next voltage vector with larger (or smaller) value of βcomponent is applied to bring the error in the current vector within the tolerance region. Similarly, if the output current exceeds the tolerance region from the left (or right) side, the next voltage vector with larger value (or smaller) of αcomponent is applied to bring the error in current vector inside the tolerance region. For all other cases, the current controller must select zero voltage vectors to achieve minimum switching losses.

The DSTATCOM output voltage in stationary reference frame can have four values of non-zero voltage vectors in αaxis and three values of non-zero voltage vectors in βaxis, as shown in Figure-7. Therefore, a current controller of four level comparators in αaxis and three-level comparators in βaxes is used in this method. The outputs of hysteresis comparators $D\alpha$(in αaxis) and $D\beta$(inβaxis) determine the output voltage vector of theDSTATCOM, as shown in Figure-7 and tabulated in Table-2. These vectors are chosen in such a way that the slope of the error in current vector and error is within the square tolerance region. For each 60°, the comparator outputs, $D\alpha$and $D\beta$, remain constant from which thesector information of reference voltage vector V_n^*isobtained. Hence, the controller should select two non-zero voltage vectors adjacent to the reference voltage vector$V_n^*$and a zero voltage vector. Once the value of $D\alpha$or $D\beta$changes, the reference voltage vector V_n^* moves to thenext sector. In each sector, the controller selects two non-zero voltage vectors and a zero vector, as done in the previous sector. Thus, by this method, the switching frequency of the inverter is significantly reduced.

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Simulation Results

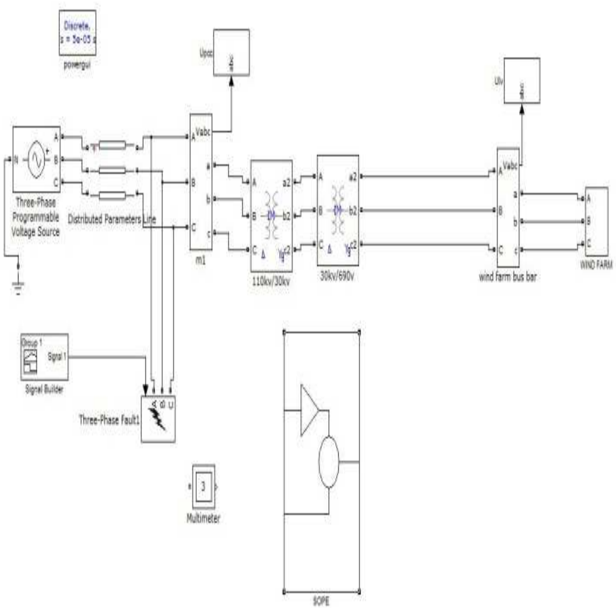
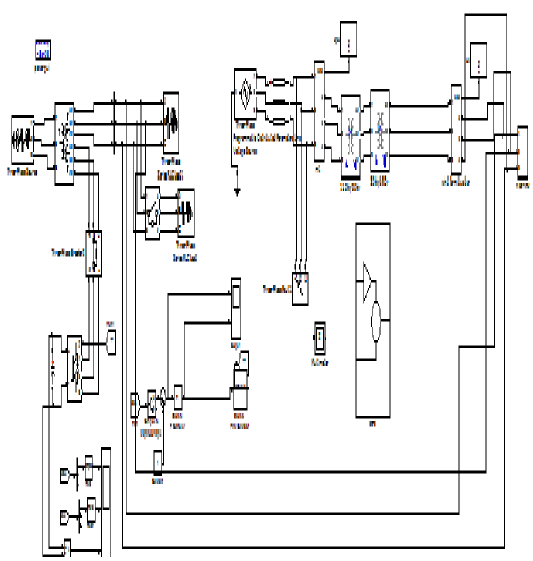
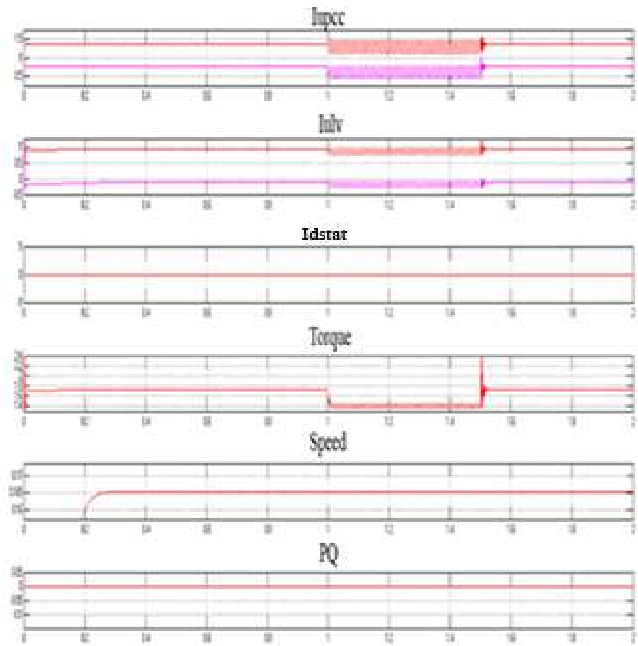


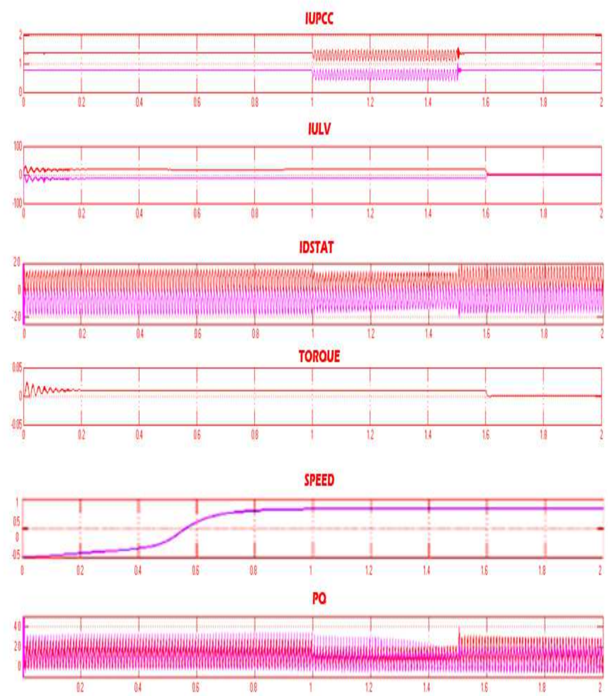
Figure 4. Simulink Model of Wind Turbine Fed Fsig Without D-STATCOM

Figure 5. Simulink Model of Wind Turbine Fed FsigWith DSTATCOM
1ph-50%



Wind Turbine Fed FsigWithoutD-STATCOM-1ph50%





Wind Turbine Fed FsigWith D-STATCOM-1ph50%

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Conclusion

In this project a windturbine fed fixed speed induction generator is modeled under asymmetric grid fault 1ph-50%. To mitigate these faults D-STATCOMis injected into the windturbine fed fixed speed induction generator. It also compensates the positive and negative sequence voltage and current. The respective waveforms are verified for without and with D-STATCOM

A. Appendix

TABLE I. SIMULATION PARAMETERS

Wind Farm Induction Generator	Simulation Parameters
Base Apparent Power	575 MW
Rated Active Power	50 MW
Rated Voltage (Line To Line)	690 V
Stator Resistance	0.0108 p.u
Stator Stray Impedance	0.107 p.u
Mutual Impedance	4.4 p.u
Rotor Impedance	0.01214 p.u
Rotor Stray Impedance	0.1407 p.u
Compensation Capacitors	0.17 F
Mechanical Time Constant	3s

B. Grid And Transformer Parameters

	Grid	High Voltage Transformer	Medium Voltage Transformer
Base Apparent Power and Rated Voltage	1000 MW 110 KV	100 MW 30 KV	100 MW 690 V
Stray Impedance	0.98 p.u	0.05 p.u	0.1 p.u
Resistance	0.02 p.u	0.01 p.u	0.02 p.u

Acknowledgement

I like to dedicate this paper to my mother Mrs. P. Jayalakshmi, my father Mr. N. Periyasamy, and my sister Miss. P. SenthilKumari.. Special thanks to my close friend Mr. C. Prakash.

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